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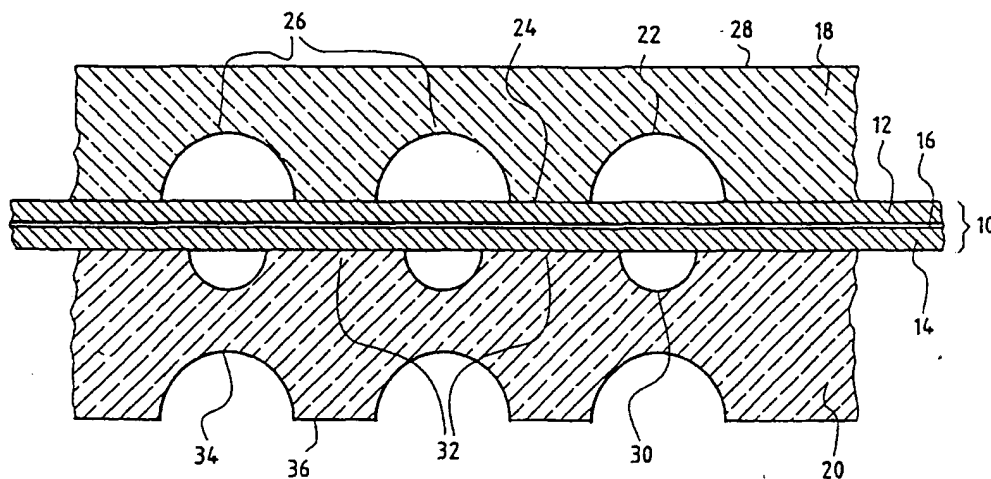
(57) Abstract

An electrically conductive, fuel cell fluid flow field plate comprises a first major surface, a second major surface disposed opposite said first major surface, and a plurality of parallel substantially straight channels formed in at least one of the first and second major surfaces. The channels are separated by lands, and at least one of the plurality of channels has an open width less than about 0.75 millimeter. The channels preferably have a length to cross sectional area ratio of between about 2180:1 to about 6200:1. When the fluid flow field plate is used in a fuel cell operating at a current density higher than about 500 mA/cm$^2$, the pressure differential between the inlets and outlets of the oxidant flow field channels is between about 138 millibars and about 400 millibars. Such fluid flow field plates may be formed by embossing or molding.

# FUEL CELL FLUID FLOW FIELD PLATE
## AND METHODS OF MAKING FUEL CELL FLOW FIELD PLATES

### Field of the Invention

The present invention relates to a fluid flow
field plate for a fuel cell and methods of making
fuel cell flow field plates.  More particularly, the
5   invention relates to a fuel cell fluid flow field
plate comprising a plurality of substantially
straight parallel elongated fluid flow field
channels for directing at least one reactant and/or
coolant fluid stream within a fuel cell.

10

### Background of the Invention

Electrochemical fuel cells convert reactants,
namely fuel and oxidants, to generate electric power
15   and reaction products.  Electrochemical fuel cells
generally employ an electrolyte disposed between two
electrodes, namely a cathode and an anode.  The
electrodes each comprise an electrocatalyst disposed
at the interface between the electrolyte and the
20   electrodes to induce the desired electrochemical
reactions.  The fuel fluid stream which is supplied
to the anode may be a gas such as substantially pure
hydrogen or a reformate stream comprising hydrogen.
Alternatively, a liquid fuel stream such as, for
25   example, aqueous methanol may be used.  The oxidant
fluid stream, which is supplied to the cathode,

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typically comprises oxygen, such as substantially
pure oxygen, or a dilute oxygen stream such as air.

Solid polymer fuel cells employ a solid polymer
electrolyte, or ion exchange membrane. The membrane
5    is typically interposed between two electrode
layers, forming a membrane electrode assembly
("MEA"). While the membrane is typically proton
conductive, it also acts as a barrier, isolating the
fuel and oxidant streams from each other on opposite
10   sides of the MEA. The MEA is typically disposed
between two plates to form a fuel cell assembly.
The plates act as current collectors and provide
support for the adjacent electrodes. The assembly
is typically compressed to ensure good electrical
15   contact between the plates and the electrodes, in
addition to good sealing between fuel cell
components. A plurality of fuel cell assemblies may
be combined in series or in parallel to form a fuel
cell stack. In a fuel cell stack, a plate may be
20   shared between two adjacent fuel cell assemblies, in
which case the plate also serves as a separator to
fluidly isolate the fluid streams of the two
adjacent fuel cell assemblies.

Fuel cell plates known as fluid flow field
25   plates have open channels formed in one or both
opposing major surfaces for directing reactants
and/or coolant fluids to specific portions of such
major surfaces. The open channels also provide
passages for the removal of reaction products,
30   depleted reactant streams, and/or heated coolant
streams. For an illustration of a fluid flow field
plate, see, for example, U.S. Patent No. 4,988,583.
Where the major surface of a fluid flow field plate

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faces an MEA, the open channels typically direct a
reactant across substantially all of the
electrochemically active area of the adjacent MEA.
Where the major surface of a fluid flow field plate

5  faces another flow field plate, the channels formed
by their cooperating surfaces may be used for
carrying a coolant for controlling the temperature
of the fuel cell.

Some early experimental fuel cell fluid flow

10 field plates incorporated straight flow field
channels. These early flow field plates were
generally made from rigid, suitably electrically
conductive materials, such as, for example,
composites comprising resin and graphite or carbon

15 fibers. The flow field channels were typically
milled using a cutting tool. These materials and
the milling procedure limited the size and shape of
conventional flow field channels. Early
experimental fluid flow field plates were used in

20 experimental fuel cells operating at lower current
densities (i.e., typically less than about 380
milliamps per square centimeter ($mA/cm^2$)). However,
early experimental fluid flow field plates of this
type yielded poor performance when used in fuel

25 cells operated at higher current densities, such as,
for example, higher than about 500 $mA/cm^2$. Present

&  day fuel cells may operate at even higher current
densities, such as, for example, higher than 1000
$mA/cm^2$.

30      A factor that contributes to the observed poor
performance is poor water management within fuel
cells using conventional straight flow field
channels. An increase in current density typically

results in, inter alia, a corresponding increase in
the rate of production of reaction product water.
If reaction product water accumulates within the
reactant flow field channels, the water may prevent
5    the reactants from accessing the electrocatalyst at
the membrane-electrode interface, causing a decrease
in fuel cell performance.

Furthermore, a problem with conventional
straight path fluid flow channels may be the
10   relatively large cross-sectional area of channels.
One objective of early experimental fuel cells was
to reduce pressure losses in the flow field to
reduce parasitic energy demands of the reactant
stream delivery devices. The aforementioned
15   conventional milling methods also precluded the
fabrication of channels with smaller cross-sectional
areas because milling methods are impractical for
producing fluid flow field plates with channel
widths less than 0.75 millimeter. For example, it
20   is difficult to maintain consistent channel
dimensions using conventional milling methods
because the cutting tools wear down. For smaller
channels, variations in channel dimensions caused by
cutting tool wear can be significant, whereas for
25   larger channels, the same magnitude of variation is
less significant when the variations in cross
sectional area are considered as a percentage of the
total cross sectional area. A consequence of the
milled flow field channels is that, because of the
30   channel size, they are more prone to obstruction by
reaction product water in the fuel cell because the
fluid velocity is lower and the pressure

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differential between the channel inlet and outlet is
less.

Increasing the pressure differential (i.e., the
pressure drop) between a reactant flow field channel
5   inlet and outlet may be used to reduce or eliminate
the accumulation of product water; see, for example,
U.S. Patent Nos. 5,260,143, 5,366,818, and 5,441,819
which are hereby incorporated by reference in their
entirety.  However, higher pressure differentials
10  must be balanced against larger parasitic energy
demands.

One approach to increasing the pressure
differential is to increase the length of the
channels.  However, because of the relatively large
15  cross-sectional area of conventional milled straight
channels, to produce a sufficiently large pressure
differential, the fluid flow field channel would
need to be extremely long or the fluid flow rate
would need to be dramatically increased.  For
20  example, the following table shows theoretical
calculations of the channel length for conventional
channels with a width and depth of 0.75 mm.  These
calculations show that, to obtain a pressure drop of
about 200 mbar using conventional channels, the
25  channel length must be about 1200 millimeters long
(i.e. requiring a electrochemically active area with
a length of about 1200 millimeters).

EXAMPLE A

30

| Parameter | Value |
|-----------|-------|
|           |       |

| Electrochemically Active Area | 300 cm$^2$ |
|---|---|
| Power Density | 1000 mA/cm$^2$ |
| Fluid | Air |
| Stoichiometry | 1.5 |
| Width of Lands Between Channels | 0.5 millimeter |
| Flow Field Flow Rate | 7.54 liters/minute |
| Flow Rate For Single Channel | 0.377 liters/minute |
| Number of Channels | 20 |
| Channel Length | 1200 millimeters |
| Channel Cross-Sectional Area | 0.563 mm$^2$ |
| Width of Channel Area | 25 millimeters |
| Ratio of Channel Length to Channel Cross-Sectional Area | 2133:1 |
| Ratio of Length to Width For Channel Area | 48:1 |

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In Example A, the channel length of 1200 millimeters
results in a length to width ratio for the
electrochemically active area of about 48:1.
Conventional fuel cell plates have not typically
5    employed such extremely elongated flow field plates.
One reason for avoiding such elongated plates
relates to their structural properties.  Another
reason is that such shapes have a much higher ratio
between the perimeter and the area.  Seals are
10   generally located around the perimeter of a fluid
flow field plate to prevent leakage of the fuel cell
fluids, such as, the reactants and coolants.  By
reducing the perimeter length, the plate area
occupied by seals is reduced, allowing the fuel cell
15   to be made smaller and/or a larger percentage of the
area to be allocated for the electrochemically
active area.  With reference to Example A, for a
channel area width of 25 millimeters and a channel
length of 1200 millimeters, the perimeter of the
20   channel area is 2450 millimeters.  Assuming that the
sealing area is about 3 millimeters wide, the
sealing area needed to surround the channel area
will about 7350 mm$^2$, which is almost 25 per cent of
the electrochemically active area.  Reducing the
25   length by half while preserving the same
electrochemically active area (i.e. a channel area
width of 50 millimeters and a channel length of 600
millimeters) reduces the channel area perimeter to
1300 millimeters and the corresponding sealing area
30   to 3900 mm$^2$ (i.e., about 13 per cent of the
electrochemically active area).  Accordingly,
reducing seal area results in a higher power
density.  Therefore, to reduce the plate area

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required for seals, conventional fuel cells have
typically been made more square or round, rather
than elongated.

Instead of fabricating extremely elongated
5   straight fuel cell channels, another approach to
increasing the pressure differential without
reducing the channel cross-sectional area is to
employ serpentine channels; see for example U.S.
Patent Nos. 4,988,583 and 5,108,849, which are
10  hereby incorporated by reference in their entirety.
With a serpentine channel, the bends cause a
pressure drop, and the channel length may be
increased without requiring a fluid flow field plate
with a dimension as long as the channel.
15       However, there are several advantages
associated with substantially straight channels.
For example, one advantage is that, compared to non-
linear channels where there may be eddies near bends
in the channel, straight channels provide less
20  places for water to accumulate in the channels.
Another advantage is that there is less turbulence
in fluids flowing in the channels since there are no
corners.  Turbulent fluid flow may eventually damage
fuel cell components, reducing the reliability and
25  service life of the fuel cell.  Also, if the fuel
cell employs a plurality of parallel straight
channels, every channel on the plate may easily be
made with exactly the same length, which may not
necessarily be true for channels that follow a
30  serpentine or tortuous path.

Another advantage of substantially straight
channels is that there tends not to be a substantial
pressure differential between adjacent channels.  A

pressure differential between adjacent channels may
result in fluids short-circuiting or by-passing of
certain channel portions, particularly at the
channel corners, in non-linear channels, where the
5    fluid may traverse the land to an adjacent channel
which has a lower fluid pressure. Fluid flow field
plates employing a plurality of parallel serpentine
channels also may have a pressure differential
between adjacent channels.
10        Another problem with channel corners in
channels having sloped side walls is that they are
especially susceptible to undesirably deflecting the
fluid stream out of the channel, into the adjacent
electrode, and across the adjacent land area. This
15   is one of the reasons why conventional channels have
typically employed side walls that are perpendicular
to the major surface of the adjacent MEA.
          Yet another advantage of straight channels
relates to temperature control in the fuel cell.
20   The temperature gradient across the fuel cell may be
controlled so that, for example, the temperature
increases in the direction of the oxidant flow
direction. Non-linear channels may produce a
channel pattern wherein adjacent channels have
25   conflicting temperature requirements, upsetting the
temperature control along the channel. The
temperature gradient, in combination with a pressure
differential between the channel inlet and outlet,
may be advantageously used to control the relative
30   humidity of the oxidant stream, and thereby improve
the removal of excess water from within the fuel
cell. With substantially straight channels the

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oxidant and coolant channels may be parallel and the
oxidant and coolant may flow in the same direction.
        Accordingly, there are numerous potential
advantages of conventional fluid flow field plates
5      that employ straight channels.  However, heretofore,
fluid flow field plates using conventional straight
channels have provided satisfactory performance at
low current densities, but have been unable to
provide satisfactory performance at higher current
10     densities.  Current density is defined as the number
of milliamps per square centimeter of
electrochemically active area.  In the context of
this disclosure, "high" current density is defined
as current densities of 500 mA/cm$^2$ and higher.  In
15     this context, performance may be measured by
measuring the cell voltage at a particular current
density, wherein at a given current density, higher
cell voltage signifies higher performance.  An
improved fluid flow field plate that incorporates
20     substantially straight channels provides improved
performance at high current densities compared to
conventional fluid flow field plates.


25     Summary of the Invention
        In one embodiment, an electrically conductive,
fuel cell fluid flow field plate comprises:
        (a)    a first major surface;
        (b)    a second major surface, opposite to the
30             first major surface; and
        (c)    at least one substantially straight
               channel formed in the first major surface,
               wherein at least one channel has an open

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width less than about 0.75 millimeter and
a length which extends substantially
between two opposing edges of the fluid
flow field plate.

5          The preferred fuel cell is a solid polymer fuel
cell.  The fluid flow field plate preferably
comprises a plurality of substantially straight
parallel channels separated by lands.  Each of the
plurality of substantially straight channels

10    preferably has an open width less than about 0.75
millimeter and extends substantially between two
opposing edges of the fluid flow field plate.  Each
one of the plurality of channels preferably has
about the same length.  There may be some variation

15    in the length of fluid passages for fluidly
connecting each of the channels to a manifold.  Non-
linear fluid passages or flow guides may be employed
to direct the fluid from the substantially straight
channels to the manifolds.  In operation, the

20    pressure drop in the substantially straight channels
is relatively large, compared to the pressure drop
in the non-linear passages, so any differences in
the pressure are insignificant between each one of
the plurality of substantially straight channels.

25          A preferred fluid flow field plate has an open
width of about 0.5 millimeter for each one of the
plurality of substantially straight channels.  The
channel may have a semicircular cross-section with a
radius of about 0.25 millimeter.

30          The lands may comprise a substantially flat
surface parallel to the plane of the first major
surface.  These lands may have rounded edges with a
radius of curvature of at least 0.15 millimeter next

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to adjacent ones of the channels.  Alternatively,
the lands may comprise a convex ridge.  The shape of
the lands is formed so as to provide a surface that
may be pressed against the relatively thin and
5    fragile MEA without causing any damage to it.
Accordingly, lands with sharp profiles are
undesirable.  Further, it is undesirable for lands
bearing against opposing side of the MEA to be
offset so as to apply shear forces to the MEA.  In a
10   preferred embodiment, the lands have a flat surface
with a width between about 0.5 millimeter and 0.9
millimeter.

The channels fluid flow field plates are desirable to
improve the power density of a fuel cell or fuel
15   cell stack. A preferred flow field plate has a
maximum overall thickness of about 0.8 millimeter
between the first and second major surfaces.  Fluid
flow field plates with channels formed on both
opposing major surfaces may have a thickness of
20   about 1.1 millimeter for channels which have depths
of 0.25 millimeter on one major surface, and about
0.4 millimeter on the opposing major surface.  To
provide adequate structural strength, the fluid flow
field plate has an absolute minimum web thickness of
25   between about 0.35 and 0.6 millimeter.  Preferably
the web thickness is designed to be at least 0.4
millimeter to allow for tolerance variations during
manufacturing.

The channels preferably have a depth that is
30   approximately half of the channel open width.  For
example, for a channel with an open width of about
0.8 millimeter, the maximum channel depth may be
about 0.4 millimeter (i.e. for a semicircular

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channel cross-section, the radius curvature is about 0.4 millimeter).

Fuel cell fuel stream flow rates are generally lower than oxidant stream flow rates.  Accordingly,
5    compared to oxidant channels, smaller channels may be generally employed for fuel channels.  For example, in a fuel cell, if substantially straight oxidant channels with a semicircular cross-section have an open width of about 0.84 millimeter,
10   corresponding substantially straight fuel channels with a semicircular cross-section and an open width of about 0.5 millimeter may be employed.

Channels with cross-sectional shapes other than semicircles may also be employed.  For example, the
15   channel may have a flat base and opposing side walls that diverge outwardly from the base towards the open width.  An advantage of outwardly diverging side walls is that this feature facilitates forming the plate by molding or embossing.

20   The fluid flow field plate may comprise expanded graphite, being formed, for example, from flexible graphite foil, which may be formed into a plate by roller embossing methods.  After embossing, the plate may be impregnated with a low viscosity
25   thermosetting resin.

In another embodiment, an electrically conductive, fuel cell fluid flow field plate comprises:

(a)    a first major surface;
30    (b)    a second major surface, opposite to the first major surface; and

(c)    a plurality of parallel, substantially straight channels formed in at least one

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of the first and second major surfaces,
wherein at least one of the plurality of
channels has a length to cross-sectional
area ratio of between about 2180:1 to

5        about 6200:1

A preferred fluid flow field plate has a
plurality of channels that each have a length to
cross-sectional area ratio of about 2190:1.   In
another preferred embodiment, the fluid flow field

10   plate has a plurality of channels that each have a
length to cross-sectional area ratio of about
6180:1.   A larger length to cross-sectional area
ratio may be employed for lower flow rates across
the fluid flow field plate, to accomplish the

15   desired pressure drop.

The fluid flow field plate preferably has a
plurality of channels that define a channel area
that corresponds to the electrochemically active
area of the MEA interposed between respective

20   oxidant and fuel channel areas.   The preferred
channel area has a length to width ratio greater
than about 3:1 and less than about 48:1.   For
example, a preferred channel area has a length to
width ratio is about 12:1.

25        The following table illustrates two preferred
embodiments of a fluid flow field plate having
channel areas that have length to width ratios
within the preferred range.   Example 1 assumes a
higher flow rate than Example 2, as might be the

30   case if, for example, Example 1 related to oxidant
channels and Example 2 related to fuel channels.
The tables also show that in these examples, the

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ratio between the channel length and the cross-
sectional area is also within the desired range:

<u>EXAMPLE 1</u>

5

| Parameter | Value |
|---|---|
| Electrochemically Active Area | 300 $cm^2$ |
| Power Density | 1000 $mA/cm^2$ |
| Fluid | Air |
| Stoichiometry | 1.5 |
| Width of Lands Between Channels | 0.5 millimeter |
| Flow Field Flow Rate | 7.54 liters/minute |
| Flow Rate For Single Channel | 0.203 liters/minute |
| Pressure Drop | approx. 200 mbar |
| Number of Channels | 37 |
| Channel Length | 600 millimeters |
| Channel Cross-Sectional Area | 0.277 $mm^2$ |

| Width of Channel Area | 50 millimeters |
|---|---|
| Ratio of Channel Length to Channel Cross-Sectional Area | 2166:1 |
| Ratio of Length to Width For Channel Area | 12:1 |

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EXAMPLE 2

| Parameter | Value, |
|---|---|
| Electrochemically Active Area | 300 $cm^2$ |
| Power Density | 1000 $mA/cm^2$ |
| Fluid | Reformate (69% $H_2$) |
| Stoichiometry | 1.2 |
| Width of Lands Between Channels | 0.84 millimeter |
| Flow Field Flow Rate | 3.65 liters/minute |
| Flow Rate For Single Channel | 0.10 liters/minute |
| Pressure Drop | approx. 345 mbar |
| Number of Channels | 36 |
| Channel Length | 600 millimeters |
| Channel Cross-Sectional Area | 0.098 $mm^2$ |
| Width of Channel Area | 50 millimeters |

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| Ratio of Channel Length to Channel Cross-Sectional Area | 6184:1 |
|---|---|
| Ratio of Length to Width For Channel Area | 12:1 |

In Example 1, the channels have an open width of
about 0.84 millimeter and a semicircular cross

5      sectional shape.  In Example 2, the channels have an
open width of about 0.5 millimeter and a
semicircular cross sectional shape.  Examples 1 and
2 show that, compared to Example A, smaller channel
cross-sectional areas enable fluid flow field plates

10     to employ shorter straight channel lengths so that
the ratio of length to width for the
electrochemically active area may be reduced.  These
advantages could not be realized by fluid flow field
plates employing conventional milled channels with

15     larger cross-sectional areas, such as the channels
of Example A.
        A corresponding electrochemical fuel cell
comprises:
        (a)   a fuel flow field plate with opposing

20             first and second major surfaces;
        (b)   an oxidant flow field plate with opposing
               first and second major surfaces;
        (c)   a membrane electrode assembly interposed
               between the first major surfaces of the

25             fuel and oxidant flow field plates; and

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      (d)   at least one substantially straight fuel
channel formed in the first major surface
of the fuel flow field plate,
wherein the fuel channel has an open width less

5    than 0.75 millimeter and a length which extends
substantially between two opposing edges of the
fluid flow field plate.

    A plurality of fluid flow field plates as
described herein may be employed in the

10   electrochemical fuel cell.  That is, the
electrochemical fuel cell may comprise a plurality
of parallel straight oxidant channels formed in the
first major surface of the oxidant flow field plate.
The plurality of oxidant channels may extend from

15   an oxidant inlet to an oxidant outlet, wherein at
least one of the plurality of oxidant channels has
an open width of about 0.85 millimeter or less.  The
plurality of fuel channels may be oriented parallel
to the plurality of oxidant channels.

20      The spacing of the channels may be arranged to
avoid applying shear forces to the MEA.  For
example, to avoid lands on the oxidant flow field
plate from being positioned within the channels on
the fuel flow field plate, the spacing between the

25   centers of the oxidant channels may be made the same
as the spacing between the centers of the fuel
channels.  That is, if the fuel channels have a
width of 0.5 millimeter, and the oxidant channels
have a width of 0.84 millimeter, the lands between

30   adjacent oxidant channels may have a width of about
0.5 millimeter, and the lands between adjacent fuel
channels may have a width of about 0.84 millimeter.
In this way, the lands on the respective fuel and

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oxidant flow field plates may be aligned so that a
land area is never unsupported on the opposite side
of the MEA by being aligned with an opposite
channel.  In one embodiment, the center of each of
5    the plurality of fuel channels is aligned with the
center of one of the plurality of oxidant channels.
        When the fuel cell is one of a plurality of
fuel cells arranged in a stack, coolant channels may
be provided between the second major surfaces of
10   adjacent ones of the fuel and oxidant flow field
plates.  That is, channels formed in at least one of
the second major surfaces, and the opposing second
major surface of an adjacent fuel cell cooperate to
form coolant passages.
15       In an electrochemical fuel cell stack, the fuel
cells are preferably oriented such that the oxidant
and fuel channels are substantially horizontal.  In
this embodiment, liquids such as water, which may
accumulate within the channels, may drain in the
20   direction of the fluid flow.  That is, there are no
low points in the channel where water may collect.
Because the channels are straight and substantially
horizontal, water may drain in whichever direction
the fluid in the channel is flowing.
25       In one embodiment of the electrochemical fuel
cell, the oxidant and fuel channels have a length of
about 600 millimeters.
        The electrochemical fuel cell preferably
further comprises internal fuel and oxidant internal
30   manifolds formed by aligned and fluidly sealed
openings provided in the fuel flow field plate, the
oxidant flow field plate and the membrane electrode
assembly.  In a preferred embodiment, the flow field

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plates are arranged with the first and second major
surfaces in a substantially vertical plane with the
fuel and oxidant manifolds extending substantially
horizontally through the stack.  The fuel and.
5    oxidant manifolds preferably each have a low point
that is lower than a lowest one of the corresponding
fuel and oxidant channels.

     Another preferred electrochemical fuel cell
comprises:

10        (a)   a fuel flow field plate with opposing
                first and second major surfaces;
          (b)   an oxidant flow field plate with opposing
                first and second major surfaces;
          (c)   a membrane electrode assembly interposed
15              between the first major surfaces of the
                fuel and oxidant flow field plates;
          (d)   a plurality of parallel substantially
                straight fuel channels formed in the first
                major surface of the fuel flow field
20              plate, the fuel channels extending from a
                fuel inlet to a fuel outlet; and
          (e)   a plurality of parallel substantially
                straight oxidant channels formed in the
                first major surface of the oxidant flow
25              field plate, the oxidant channels
                . extending from an oxidant inlet to an
                oxidant outlet;
     wherein there is a pressure differential
between the inlets and outlets of the oxidant and
30   fuel channels of between about 138 millibars and
about 400 millibars when the fuel cell is operating
at a current density higher than about 500 mA/cm$^2$.

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A method of making a fluid flow field plate as
described herein comprises:

    (a)    providing a sheet of compressible,
           electrically conductive sheet material

5           having two oppositely facing major
           surfaces; and

    (b)    embossing the first major surface to form
           the at least one open-faced channel.

The embossing method is particularly suited to

10  forming channels with open widths less than 0.75
millimeter. Expanded graphite may be employed as
one of the materials for forming the fluid flow
field plates. For high speed manufacturing, a
roller embossing machine may be employed to emboss a

15  sheet of expanded graphite. The roller embossing
machine may further comprise cutters mounted on a
roller for cutting the sheet to a desired shape.
The method may further comprise forming at least one
opening in the sheet and forming a fluid passage

20  between the opening and the channel. The embossed
plate preferably has a minimum web thickness of
between 0.35 millimeter and 0.6 millimeter. After
embossing, the plate may be impregnated with a low
viscosity thermosetting resin.

25  Another method of making the fluid flow field
plate described herein comprises:

    (a)    providing a mold for forming the plate
           wherein the mold provides channels on a
           major surface of the plate and sealing

30           areas which circumscribe an area defined
           by the channels;

    (b)    depositing an electrically conductive
           material into the mold;

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     (c)   molding the electrically conductive
material until it is molded into the shape
defined by the mold; and

     (d)   removing a molded plate from the mold.

5       The electrically conductive material employed
by the molding method may be a composite material
comprising carbon or graphite.  The material may
comprise a thermosetting and/or a thermoplastic
resin.

10      Different types of molding methods may be used
to form the fluid flow field plate.  For example,
the molding method may be a compression molding
process or an injection molding process.

15

Brief Description of the Drawings

      The advantages, nature and additional features
of the invention will become more apparent from the
following description, together with the
20   accompanying drawings, which illustrate specific
embodiments of the fluid flow field plates of the
present invention.

      FIG. 1 is a partial cross-sectional view of a
fuel cell that depicts a membrane electrode assembly
25   interposed between an oxidant fluid flow field plate
and a fuel fluid flow field plate.

      FIGs. 2A through 2D are examples of different
embodiments of channel cross section shapes.  In
particular, FIG. 2A depicts concave channels
30   separated by convex land areas; FIG. 2B depicts
semi-circular channels separated by flat land areas
with rounded edges; FIG. 2C depicts a trapezoid flow
field channel also separated by flat land areas; and

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FIG. 2D depicts a trapezoid channel with rounded
corners and land edges.

FIG. 3A is a plan view of an oxidant fluid flow
field plate, depicting oxidant channels formed in
5    the major surface of the plate which faces the
cathode of the membrane electrode assembly when
incorporated into a fuel cell assembly.

FIG. 3B is a side elevation view of the oxidant
fluid flow field plate of FIG. 3A.

10   FIG. 3C is a plan view of the oxidant fluid
flow field plate of FIG. 3A, depicting the major
surface of the plate which faces away from the
membrane electrode assembly, that is, the major
surface of the plate which is opposite the major
15   surface of FIG. 3A.

FIG. 4A is a plan view of a fuel fluid flow
field plate, depicting fuel channels formed in the
major surface of the plate which faces the anode of
the membrane electrode assembly when the plate is
20   incorporated into a fuel cell assembly.

FIG. 4B is a side elevation view of the fuel
flow field plate of FIG. 4A.

FIG. 4C is a plan view of the fuel fluid flow
field plate of FIG. 4A, depicting coolant fluid flow
25   field channels formed in the major surface which
faces away from the membrane electrode assembly,
that is, the major surface of the fuel flow field
plate which is opposite the major surface of FIG.
4A.

30   With reference to all of the FIGURES, like
numbers are used to denote like components.

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### Detailed Description of the Preferred Embodiments

FIG. 1 illustrates a partial cross sectional view of a solid polymer fuel cell.  MEA 10 comprises a cathode 12, an anode 14, and a solid polymer
5    electrolyte 16 interposed therebetween.  The thickness of MEA 10 in the assembled cell is less than 0.35 millimeter.  MEA 10 is interposed between oxidant flow field plate 18 and fuel flow field plate 20 to form a fuel cell assembly.  Oxidant and
10   fuel flow field plates 18 and 20 each have two parallel major surfaces with a respective one of these major surfaces facing and contacting MEA 10 to provide support and electrical contact.

Oxidant channels 22, separated by lands 24, are
15   formed in the major surface of oxidant flow field plate 18, which faces MEA 10.  In the illustrated embodiment, oxidant channels 22 have a semi-circular cross section and lands 24 have substantially flat surfaces parallel to the plane of the major surfaces
20   of oxidant flow field plate 18.  In a preferred embodiment, oxidant channels 22 have an open width of about 0.84 millimeter and the lands 24 have a width of about 0.50 millimeter.  The oxidant flow field plate may have a thickness of about 0.82
25   millimeter, such that the thinnest portion of oxidant flow field plate 18 is about 0.40 millimeter thick (i.e., in the illustrated embodiment, the thinnest portion of flow field plate 18 is web portion 26 which is between flat major surface 28
30   and the deepest part of oxidant channel 22)

Fuel channels 30, separated by lands 32, are formed in the major surface of fuel flow field plate 20 which faces MEA 10.  In the illustrated

embodiment, fuel channels 30 have a semi-circular
cross section and lands 32 have substantially flat
surfaces parallel to the plane of major surfaces of
fuel flow field plate 20.  In the illustrated

5    embodiment, the centers of fuel channels 30 are
aligned with the centers of opposite oxidant
channels 22.  An advantage of this arrangement is
that the oxidant and fuel channel edges are spaced
so that they do not exert shear forces on MEA 10,

10   which may damage MEA 10.  In a preferred embodiment,
fuel channels 30 have an open width of about 0.50
millimeter and the lands have a width of about 0.84
millimeter.

     Fuel flow field plate 20 also has coolant
15   channels 34 formed in major surface 36.  The
illustrated fuel cell assembly may be one of a
plurality of fuel cell assemblies arranged in a
stack.  When the fuel cell assemblies are stacked
one on top of the other, major surface 36 and

20   coolant channels 34 cooperate with major surface 28
of an adjacent fuel cell assembly to form a
plurality of coolant passages therebetween.  Coolant
channels 34 may be formed in either major surface 28
or in major surface 36 (as illustrated).  In the

25   illustrated embodiment, coolant channels 34 are
semi-circular, have an open width of about 0.84
millimeter, and are also aligned with reactant
channels 22, 30.

     Preferably, the coolant channels are formed in
30   fuel flow field plate 20 (as illustrated) because
fuel channels 30 are generally smaller than oxidant
channels 22.  Thus, by forming coolant channels in
fuel flow field plate 20, the oxidant and fuel flow

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field plates are closer in thickness.  In the
illustrated example, fuel flow field plate 20 may
have a thickness of about 1.07 millimeters with a
web thickness of about 0.4 millimeter (i.e., for the
5    illustrated fuel flow field plate 20, the thickness
of the plate between the deepest points of fuel
channel 30 and coolant channel 34 is about 0.4
millimeter.  Alternatively, the thickness of fuel
flow field plate 20 may be reduced by offsetting
10   fuel channels 30 from coolant channels 34.  For
example, fuel channel 30 may be aligned with land 36
and coolant channel 34 may be aligned with land 32.
     In another embodiment, a corrugated material may be
employed to provide channels on opposite major
15   surfaces of a fluid flow field plate.
       The fuel and oxidant channels direct reactants
across and through the porous electrodes to the
electrocatalyst at the membrane electrode interface.
Accordingly, a large open channel area is
20   desirable.  That is, a large percentage of the major
surface of the fluid flow field plate is preferably
open channel area.  An advantage of straight
channels is that thinner land areas may be employed
between adjacent channels because there are no
25   pressure differentials between adjacent channels
(i.e. no danger of short circuiting), no bends, and,
because there are no adjacent channels where a fluid
is flowing in opposite directions on the same fluid
flow field plate.
30     The fluid distribution function of the flow
field channels must be balanced against the
structural function of the land areas, which is to
support the MEA.  The thickness and rigidity of the

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MEA limits the width of the channels, since the MEA
may deflect into the channels if the channel widths
are too wide. As shown in FIG. 1, an advantage of
straight channels is that the land areas 24 and 32
5    may be aligned so that the opposing land areas do
not exert any shear forces on the MEA. Further, the
land areas should not be too thin, so that they act
as a sharp peak that might cut into the MEA. In
addition to the structural support function, another
10   important function of the land areas is to provide
adequate thermal and electrical conductivity by
providing a sufficiently large surface area in
contact with the MEA.

Coolant channels have different functional
15   requirements from the fuel and oxidant channels.
Coolant channels are preferably shaped and sized to
reduce parasitic losses (i.e. by reducing pressure
losses), and to improve thermal contact between the
coolant and the fuel cell plates.

20       FIG. 1 illustrates a fuel cell assembly wherein
all of the fluid flow field channels are semi-
circular and separated by substantially flat land
areas. FIGs. 2A through 2D show examples of other
channel cross section shapes that may be employed
25   for oxidant, fuel, or coolant channels.
Additionally, a fuel cell assembly may employ more
than one channel shape. For example, the coolant
channels may be shaped and sized differently from
the fuel and/or oxidant channels.

30       FIG. 2A depicts concave channels separated by
convex land areas. The convex shape of the land
areas is less likely to damage an MEA. The convex
shape also widens the open area of the channel,

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facilitating the distribution of fuel or oxidant to
the adjacent electrode areas.

    FIG. 2B depicts substantially semi-circular
channels separated by substantially flat land areas

5    with rounded edges.  The rounded edges are easy to
form by embossing or molding methods.  The rounded
edges also eliminate sharp edges, while the flat
land area provides good thermal and electrical
contact between the flow field plate and the MEA.

10        FIG. 2C depicts trapezoidal flow field channels
with each channel having a flat base and sloped side
walls.  FIG. 2D illustrates an embodiment with
substantially flat land areas and a substantially
flat channel base that is similar to the embodiment

15    of FIG. 2C except that the edges are rounded.
Compared to vertical side walls, sloped side walls
are easier to form by embossing and molding methods.
 Those skilled in the art will readily recognize
that other channel and land shapes, not illustrated,

20    such as v-shapes or half-octagons, may also be used.

    FIGs. 3A through 3C illustrate three different
views of a preferred embodiment of an oxidant flow
field plate 48.  FIG. 3A is a plan view of a first
major surface of oxidant flow field plate 48

25    comprising a plurality of parallel substantially
straight oxidant channels 50.  Perimeter seal area
51 circumscribes the oxidant channel area and
through plate openings which may serve as fluid
manifold segments.  Seals may comprise gaskets,

30    molded elastomers, and the plate material itself
that cooperates with perimeter seal area 51 to form
a fluid seal.  In the absence of a fluid leak, these

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seals confine the oxidant fluid to the circumscribed
area of oxidant flow field plate 48.

In the illustrated embodiment, there are
oxidant manifold openings 52 and 54 associated with
5      opposite ends of oxidant channels 50. Oxidant
passages 56 direct the oxidant between oxidant
manifold opening 52 and oxidant channels 50.
Similarly, oxidant passages 58 direct the oxidant
between oxidant manifold opening 54 and oxidant
10     channels 50. Oxidant flow field plate 48 provides
fuel manifold openings 60 and 62 and respective
perimeter seals 64 and 66 for fluidly isolating
oxidant passages 56 and 58 from the fuel fluid
stream transported through the fuel manifolds.
15     Oxidant flow field plate 48 also provides coolant
manifold openings 68 and 70 which also have
perimeter seals to fluidly isolate oxidant passages
56 and 58 from the coolant fluid stream.

In FIG. 3A, the illustrated embodiment of
20     oxidant flow field plate 48 has an overall length of
about 734 millimeters and an overall width of about
64 millimeters. Straight oxidant channels 50 are
about 606 millimeters long. Straight oxidant
channels 50 and separating land areas occupy an area
25     of about 300 square centimeters, which generally
corresponds to the area of a fuel cell MEA
electrochemically active area which would be
disposed between the oxidant and fuel flow field
plates of FIGs. 3A and 4A. However, those skilled
30     in the art will recognize that MEAs may be
fabricated with a variety of areas and shapes. For
example, a larger MEA area may be accommodated by
adding to the width of the fluid flow field plates,

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and adding to the number of straight oxidant and
fuel channels. However, in the preferred
embodiment, increasing the MEA area does not change
the characteristics of the flow field channels, such
5    as, for example, the width of the channels, or the
ratio between the channel length and the channel
cross-sectional area, or the pressure drop from the
channel inlet to the channel outlet when the flow
field plates are used in a fuel cell which is
10   operating with a current density of 500 mA/cm$^2$ or
higher.

      FIG. 3B is a side elevation view of oxidant
flow field plate 48. In the illustrated embodiment,
the thickness of oxidant flow field plate may be as
15   thin as about 0.82 millimeter and the first major
surface defines a planar surface which is parallel
to the planar surface of the opposing second major
surface. The desire to make the oxidant flow field
plates thin to increase power density, must be
20   balanced against the structural requirements of the
fluid flow field plate. The fluid flow field plates
must not be made so thin as to compromise
dimensional stability, strength, or other structural
properties. For fluid flow field plates made from
25   expanded graphite, a web thickness of about 0.35
millimeter may be employed, but a web thickness of
about 0.4 millimeter is preferred to provide a
suitable allowance for tolerance variations which
may arise in the manufacturing process.
30    FIG. 3C is a plan view of a second major
surface of oxidant flow field plate 48. In the
illustrated embodiment, the second major surface is
substantially planar. Thus, the factors which

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determine the thickness of illustrated oxidant flow
field plate 48 are the depth of oxidant channels 50
and the web thickness measured at the deepest point
in oxidant channels 50.

5      FIG. 4A is a plan view of a first major surface
of fuel flow field plate 72 comprising a plurality
of parallel substantially straight fuel channels 74.
Perimeter seal 76 circumscribes the fuel channel
area and through plate openings which may serve as

10     fluid manifolds.  In the absence of a fluid leak,
seals associated with perimeter seal area 76 confine
the fuel to the area circumscribed by perimeter seal
area 76 of fuel flow field plate 72.

       To form a fuel cell assembly, an MEA may be

15     interposed between the first major surface of
oxidant flow field plate 48 (illustrated in FIG.
3A), and the first major surface of fuel flow field
plate 72 (illustrated in FIG. 4A).  The membrane of
the MEA is substantially impermeable to oxidant and

20     fuel, so in the absence of a leak in the membrane,
the MEA cooperates with perimeter seals 51 and 76 to
fluidly isolate the oxidant from the fuel.

       Since oxidant flow field plate 48 and fuel flow
field plate 72 cooperate with one another, their

25     respective major surfaces are similar in size and
shape.  Manifold openings shown in FIGs. 4A and 4C
align with the manifold openings shown in FIGs. 3A
and 3C. That is, fuel manifold openings 60 and 62 of
oxidant flow field plate 48 align with fuel manifold

30     openings 80 and 82 of fuel flow field plate 72.
Oxidant manifold openings 52 and 54 of oxidant flow
field plate 48 align with oxidant manifold openings
84 and 86 of fuel flow field plate 72.  Finally,

coolant manifold openings 68 and 70 of oxidant flow
field plate 48 align with coolant manifold openings
88 and 90 of fuel flow field plate 72.  In a fuel
cell stack, the manifold openings collectively form
5    fluid manifolds for supplying and exhausting
respective oxidant, fuel, and coolant fluid streams
to each fuel cell assembly.

Fuel channels 74 extend substantially between
two opposing edges of fuel flow field plate 72.
10   Fuel passages 92 and 94 provide a path for fuel to
flow between fuel channels 74 and respective fuel
manifold openings 80 and 82.  The fuel channel area,
like the oxidant channel area, corresponds to the
area of the MEA.  Thus, straight fuel channels 74
15   are about 606 millimeters long and, in the
illustrated embodiment, the area occupied by
straight fuel channels 74 is about 300 square
centimeters.  Fuel channels 74 preferably have a
semi-circular cross sectional area with an open
20   width of about 0.5 millimeter.

FIG. 4B is a side elevation view of fuel flow
field plate 72.  In the illustrated embodiment, the
fuel channel depth is about 0.25 millimeter, so if a
web thickness of 0.35 millimeter is employed, the
25   thickness of fuel flow field plate 72 may be as thin
as about 0.6 millimeter.  However, as shown by FIG.
4C, the illustrated embodiment of fuel flow field
plate 72 also comprises coolant channels 96.
Coolant channels 96 are formed in the second major
30   surface of fuel flow field plate 72.  In the
illustrated embodiment, the depth of coolant
channels is about 0.42 millimeter and the web
thickness is about 0.4 millimeter.  Accordingly, the

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illustrated fuel flow field plate 72 has a thickness
of about 1.07 millimeters.

        As shown by FIG. 4C, which is a plan view of a
second major surface of fuel flow field plate 72,
5       coolant channels 96 are fluidly connected to coolant
manifold openings 88 and 90 by respective coolant
passages 98 and 100. A fuel cell assembly comprises
an MEA interposed between an oxidant flow field
plate and a fuel flow field plate. A fuel cell
10      stack may be made by placing one fuel cell assembly
on top of another fuel cell assembly. A fuel cell
stack may comprise a plurality of fuel cell
assemblies stacked one on top of the other. In such
a fuel cell stack arrangement, the planar second
15      major surface of oxidant flow field plate 48
cooperates with the second major surface of fuel
flow field plate 72 to enclose coolant channels 96.
In the absence of a leak, seals associated with
perimeter seal area 102 confine the coolant to the
20      area circumscribed by perimeter seal area 102.

        An advantage of the preferred symmetrical
arrangement of oxidant flow field plate 48 and fuel
flow field plate 72 is that the oxidant or fuel flow
direction can be reversed without affecting fuel
25      cell performance. In a fuel cell stack, oxidant
flow field plate 48 and fuel flow field plate 72 are
preferably oriented so that the straight channels
are substantially horizontal and the fuel cell
plates are oriented with their major surfaces in a
30      vertical plane. Compared, for example, to vertical
channels or non-linear channels that may have some
vertically oriented portions, the substantially
horizontally oriented channels may readily drain

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water to manifolds on either side of the straight
channels.  In the illustrated embodiment, water
drains in the direction of fluid flow to the
associated manifold that serves as an exhaust
5    manifold.  To enhance water drainage, each reactant
manifold opening has a low point that is lower than
the lowest point of the fluidly connected channels.
The oxidant flow field plate 48 and fuel flow field
plate 72 illustrated in FIGs. 3 and 4 provide an
10   offset manifold opening area to accommodate the
oxidant manifold openings 52 and 54 and fuel
manifold openings 80 and 82 which both have low
points which are lower than the lowest oxidant and
fuel channels.  Accordingly, in fuel cell assemblies
15   where fluid flow direction is periodically reversed,
a symmetrical arrangement is preferred to facilitate
the draining of water in both directions.
The fluid flow field plate is made from a
suitably electrically conductive and substantially
20   fluid impermeable material. Expanded graphite is a
preferred material because it is sufficiently
impervious to typical fuel cell reactants and
coolants to fluidly isolate the fuel, oxidant, and
coolant fluid streams from each other.  In addition,
25   expanded graphite is compressible and embossing
processes may be used to form channels in one or
both major surfaces of an expanded graphite sheet.
For example, embossing processes may include roller
embossing or stamping methods.  Graphite is
30   chemically unreactive in a fuel cell environment
and, compared to other materials with similarly
suitable properties, graphite is relatively
inexpensive.  After the embossing procedure, the

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expanded graphite is preferably impregnated with a
resin to make the material more impervious to
reactants and coolants.  For example, a low
viscosity thermosetting resin may be used to
5     impregnate the embossed plate.  Preferably, the
impregnant also improves the structural rigidity of
the fluid flow field plate.

    The fluid flow field plate may also be made by
molding processes.  For example, a corrosion-
10    resistant metal powder, a base metal powder plated
with a corrosion resistant metal, or other
chemically unreactive electrically conducting
powders such as carbon, graphite or boron carbide
may be mixed with a polymeric binder and deposited
15    into a mold to produce an electrically conductive
fluid flow field plate.  For example, injection
molding or compression molding methods are suitable
for molding fluid flow field plates with channels
having a width of 0.75 millimeter or less.

20    Suitable polymeric binders include
thermoplastic resins suitable for injection molding
such as Kynar, a trademark for polyvinylidene
fluoride material manufactured by Penwalt.  Typical
composites include 70-90% high purity graphite
25    powder and 30-10% of polyvinylidene fluoride.

    As will be apparent to those skilled in the art
in the light of the foregoing disclosure, many
alterations and modifications are possible in the
practice of this invention without departing from
30    the spirit or scope thereof.  Accordingly, the scope
of the invention is to be construed in accordance
with the substance defined by the following claims.

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What is claimed is:


    1.    An electrically conductive, fuel cell
fluid flow field plate comprising:
        (a)    a first major surface;
        (b)    a second major surface, opposite to said
5              first major surface; and
        (c)    at least one substantially straight
               channel formed in said first major
               surface, wherein said at least one channel
               has an open width less than about 0.75
10             millimeter and a length that extends
               substantially between two opposing edges
               of said fluid flow field plate.


    2.    The fluid flow field plate of claim 1
wherein said fuel cell is a solid polymer fuel cell.

    3.    The fluid flow field plate of claim 1
wherein said plate comprises a plurality of
substantially straight parallel channels separated
by lands, wherein each of said plurality of channels
5    has an open width less than about 0.75 millimeter
and extends substantially between two opposing edges
of said fluid flow field plate.

    4.    The fluid flow field plate of claim 3
wherein each one of said plurality of channels has
about the same length.

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5.      The fluid flow field plate of claim 3
wherein each one of said plurality of channels has
an open width of about 0.5 millimeter.


6.      The fluid flow field plate of claim 3
wherein each one of said lands comprises a
substantially flat surface parallel to the plane of
said first major surface.


7.      The fluid flow field plate of claim 6
wherein said lands have rounded edges with a radius
of curvature of at least 0.15 millimeter next to
adjacent ones of said channels.


8.      The fluid flow field plate of claim 3
wherein each one of said lands comprises a convex
ridge.


9.      The fluid flow field plate of claim 3
wherein at least one of said lands has a flat
surface with a width between about 0.5 millimeter
and 0.9 millimeter.


10.     The fluid flow field plate of claim 3
wherein said flow field plate has a maximum overall
thickness of about 0.8 millimeter between said first
and second major surfaces.


11.     The fluid flow field plate of claim 9
wherein said at least one channel has a maximum
depth of about 0.4 millimeter.

12.   The fluid flow field plate of claim 3
further comprising at least one channel formed in
said second major surface.

13.   The fluid flow field plate of claim 11
wherein said flow field plate has a maximum overall
thickness of about 1.1 millimeters between said
first and second major surfaces.

14.   The fluid flow field plate of claim 12
wherein at least one of said plurality of parallel
substantially straight channels has a depth of about
0.25 millimeter and said second channel has a depth
5    of about 0.4 millimeter.

15.   The fluid flow field plate of claim 3 wherein
at least one of said plurality of parallel
substantially straight channels has a substantially
semicircular cross-sectional area with a radius less
5    than about 0.4 millimeter.

16.   The fluid flow field plate of claim 3 wherein
at least one of said plurality of parallel
substantially straight channels has a substantially
semicircular cross-sectional area with a radius of
5    less than about 0.25 millimeter.

17.   The fluid flow field plate of claim 3
wherein at least one of said plurality of channels
has a flat base and opposing side walls diverging
outwardly from said base towards said open width.

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18.    The fluid flow field plate of claim 3
wherein said fluid flow field plate comprises
expanded graphite.

19.    The fluid flow field plate of claim 18
wherein said plate is impregnated with a resin.

20.    The fluid flow field plate of claim 3
wherein said fluid flow field plate has a web
thickness between about 0.35 millimeter and about
0.6 millimeter.

21.    The fluid flow field plate of claim 3
wherein said fluid flow field plate has a web
thickness of about 0.4 millimeter.

22.    An electrically conductive, fuel cell
fluid flow field plate comprising:
    (a)    a first major surface;
    (b)    a second major surface, opposite to said
5           first major surface; and
    (c)    a plurality of parallel, substantially
           straight channels formed in at least one
           of said first and second major surfaces,
           wherein at least one of said plurality of
10          channels has a length to cross-sectional
           area ratio of between about 2180:1 to
           about 6200:1.

23.    The fluid flow field plate of claim 22
wherein each one of said plurality of channels has a
length to cross-sectional area ratio of about
2190:1.

24.  The fluid flow field plate of claim 22
wherein each one of said plurality of channels has a
length to cross-sectional area ratio of about
6180:1.

25.  The fluid flow field plate of claim 22
wherein said plurality of channels define a channel
area having a length to width ratio greater than
about 3:1 and less than 48:1.

26.  The fluid flow field plate of claim 24
wherein said length to width ratio is about 12:1.

27.  An electrochemical fuel cell comprising:
(a)  a fuel flow field plate with opposing
     first and second major surfaces;
(b)  an oxidant flow field plate with opposing
5    first and second major surfaces;
(c)  a membrane electrode assembly interposed
     between said first major surfaces of said
     fuel and oxidant flow field plates; and
(d)  at least one substantially straight fuel
10   channel formed in said first major surface
     of said fuel flow field plate, wherein
     said fuel channel has an open width less
     than 0.75 millimeter and a length which
     extends substantially between two opposing
15   edges of said fluid flow field plate.

28.  The electrochemical fuel cell of claim 27
wherein said at least one fuel channel is one of a

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plurality of parallel fuel channels separated by
lands.

29.   The electrochemical fuel cell of claim 28
wherein at least one of said plurality of fuel
channels has a width of about 0.5 millimeter.

30.   The electrochemical fuel cell of claim 28
wherein said membrane electrode assembly has a
thickness of less than about 0.35 millimeter.

31.   The electrochemical fuel cell of claim 28
further comprising a plurality of parallel straight
oxidant channels formed in said first major surface
of said oxidant flow field plate, and said plurality
5   of oxidant channels extend from an oxidant inlet to
an oxidant outlet, wherein at least one of said
plurality of oxidant channels has an open width less
than about 0.85 millimeter.

32.   The electrochemical fuel cell of claim 31
wherein said plurality of fuel channels are oriented
parallel to said plurality of oxidant channels.

33.   The electrochemical fuel cell of claim 31
wherein each one of said plurality of oxidant
channels has an open width of about 0.85 millimeter.

34.   The electrochemical fuel cell of claim 31
wherein each of said lands separating adjacent ones
of said plurality fuel channels, has a width of
about 0.85 millimeter and wherein each of said lands
5   separating adjacent ones of said plurality of

oxidant channels has a width of about 0.5
millimeter.

35.  The electrochemical fuel cell of claim 31
wherein the center of each of said plurality of fuel
channels is aligned with the center of one of said
plurality of oxidant channels.

36.  The electrochemical fuel cell of claim 27
wherein said fuel cell is one of a plurality of fuel
cells arranged in a stack and coolant channels are
provided between said second major surfaces of
5     adjacent ones of said fuel and oxidant flow field
plates.

37.  The electrochemical fuel cell of claim 36
wherein said coolant channels are formed in one of
said second major surfaces of said fuel and oxidant
flow field plates.

38.  The electrochemical fuel cell of claim 31
wherein said fuel cell is oriented such that said
oxidant and fuel channels are substantially
horizontal for draining, in the direction of the
5     fluid flow, liquids which may accumulate within said
channels.

39.  The electrochemical fuel cell of claim 31
wherein said oxidant and fuel channels have a length
of about 600 millimeters.

40.  The electrochemical fuel cell of claim 36
further comprising internal fuel and oxidant

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internal manifolds formed by aligned and fluidly
sealed openings provided in said fuel flow field
5   plate, said oxidant flow field plate and said
membrane electrode assembly.

41.   The electrochemical fuel cell of claim 40
wherein said fuel and oxidant manifolds extend
substantially horizontally through said stack.

42.   The electrochemical fuel cell of claim 41
wherein each one of said fuel manifolds has a low
point which is lower than a lowest one of said fuel
channels and each one of said oxidant manifolds has
5   a low point which is lower than a lowest one of said
oxidant channels.

43.   An electrochemical fuel cell comprising:
      (a)   a fuel flow field plate with opposing
            first and second major surfaces;
      (b)   an oxidant flow field plate with opposing
5            first and second major surfaces;
      (c)   a membrane electrode assembly interposed
            between said first major surfaces of said
            fuel and oxidant flow field plates;
      (d)   a plurality of parallel substantially
10            straight fuel channels formed in said
            first major surface of said fuel flow
            field plate, said fuel channels extending
            from a fuel inlet to a fuel outlet; and
      (e)   a plurality of parallel substantially
15            straight oxidant channels formed in said
            first major surface of said oxidant flow
            field plate, said oxidant channels

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extending from an oxidant inlet to an
oxidant outlet;

20      wherein operating said fuel cell at a current
density greater than about 500 mA/cm$^2$ creates a
pressure differential between the inlets and outlets
of said oxidant and fuel channels of between about
138 millibars and about 400 millibars.


44.   A method of making the fluid flow field
plate of claim 1, said method comprising:
        (a)   providing a sheet of compressible,
              electrically conductive sheet material
5             having two oppositely facing major
              surfaces; and
        (b)   embossing said first major surface to form
              said at least one open-faced channel.


45.   The method of claim 44 wherein a roller
embossing machine is used to emboss said sheet
material.


46.   The method of claim 45 wherein said roller
embossing machine further comprises cutters mounted
on a roller for cutting said sheet to a desired
shape.


47.   The method of claim 44 wherein said sheet
comprises expanded graphite.


48.   The method of claim 47 further comprising
impregnating said sheet with a resin after
embossing.

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49.   The method of claim 44 further comprising forming at least one opening in said sheet and forming a fluid passage between said opening and said channel.

50.   The method of claim 44 wherein said embossing compresses said sheet such that the thinnest portions of said sheet have a web thickness of between about 0.35 millimeter and 0.6 millimeter.

51.   A method of making the fluid flow field plate of claim 1, said method comprising:
   (a)   providing a mold for forming said plate wherein said mold provides channels on a
5          major surface of said plate and sealing areas which circumscribe an area defined by said channels;
   (b)   depositing an electrically conductive material into said mold; .
10    (c)   molding said electrically conductive material until it is molded into the shape defined by said mold; and
   (d)   removing a molded plate from said mold.

52.   The method of claim 51 wherein said electrically conductive material is a composite material comprising carbon or graphite.

53.   The method of claim 51 wherein said molding process is a compression molding process.
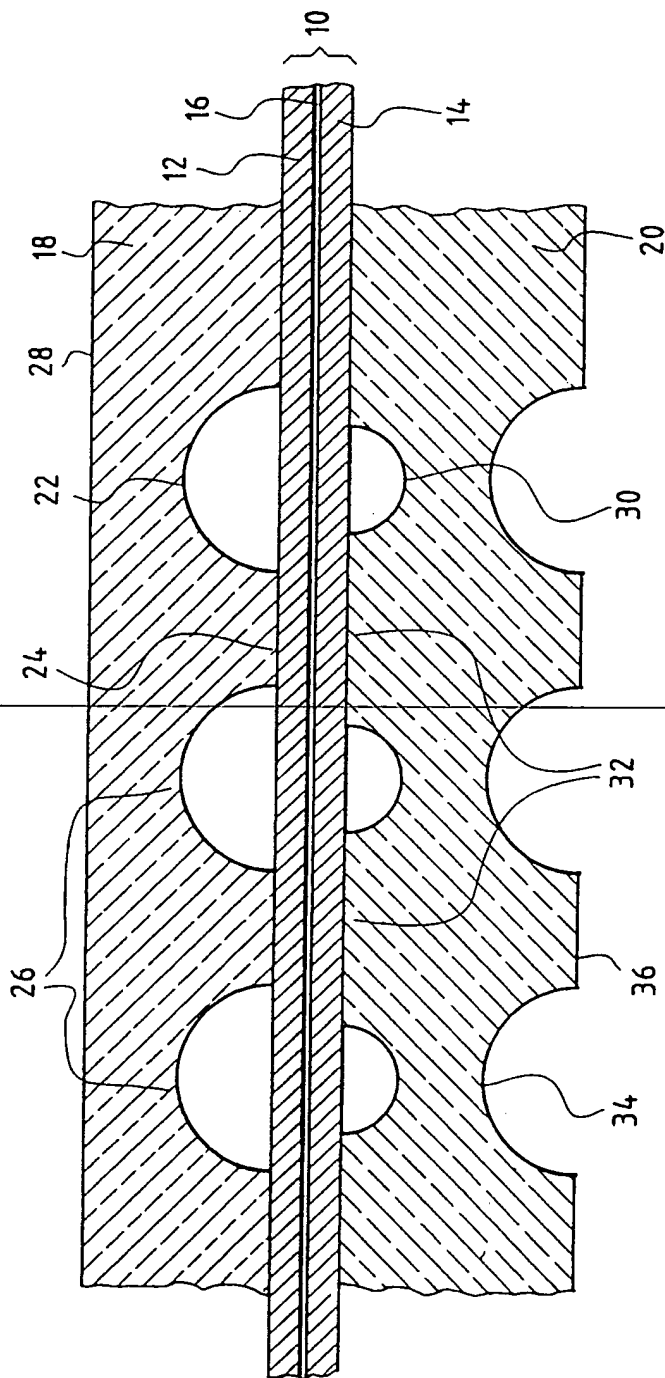
54.   The method of claim 51 wherein said molding process is an injection molding process.

55.   The method of claim 54 wherein said
electrically conductive material comprises a
thermosetting resin.

56.   The method of claim 54 wherein said
electrically conductive material comprises a
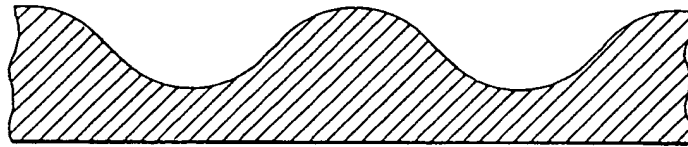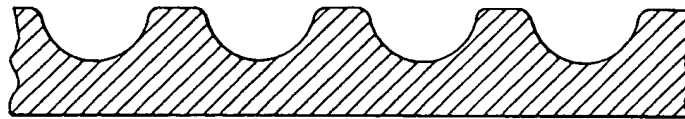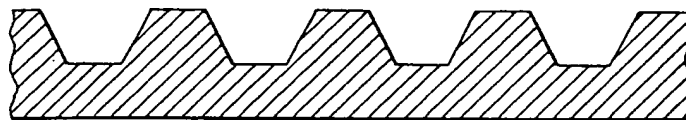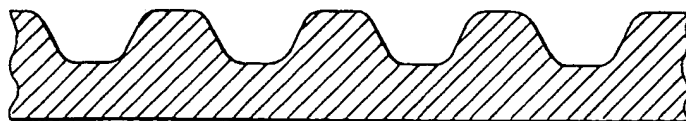thermoplastic resin.

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FIG. 1

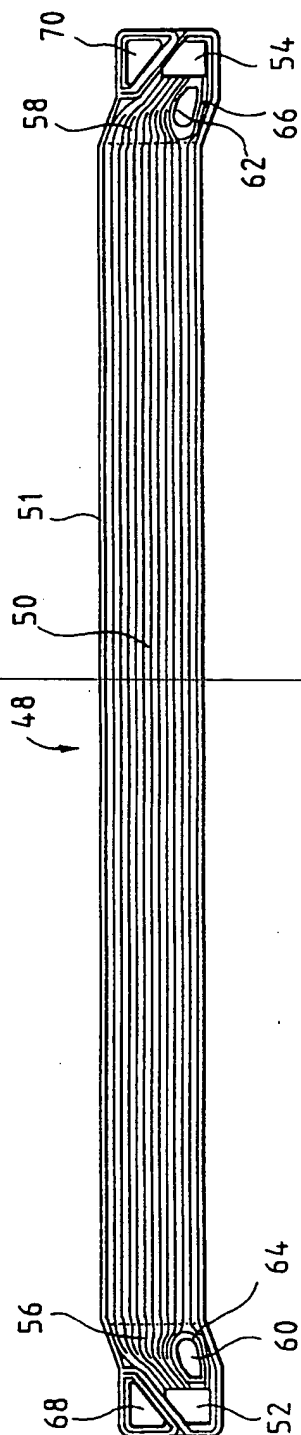2/4

FIG. 2A

FIG. 2B

FIG. 2C

FIG. 2D

FIG. 3A

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FIG. 3B

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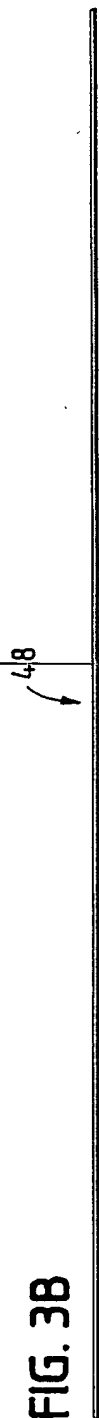
FIG. 3C
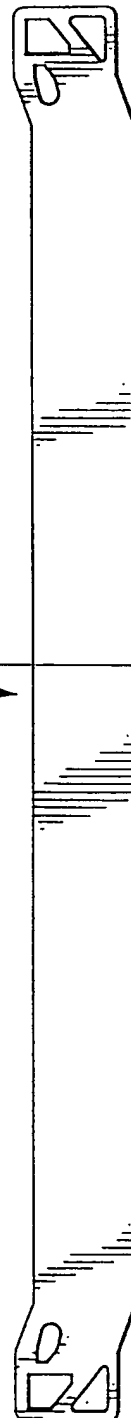
4/4

FIG. 4A

FIG. 4B

FIG. 4C

# INTERNATIONAL SEARCH REPORT

**A. CLASSIFICATION OF SUBJECT MATTER**
IPC 7   H01M8/02    H01M8/10
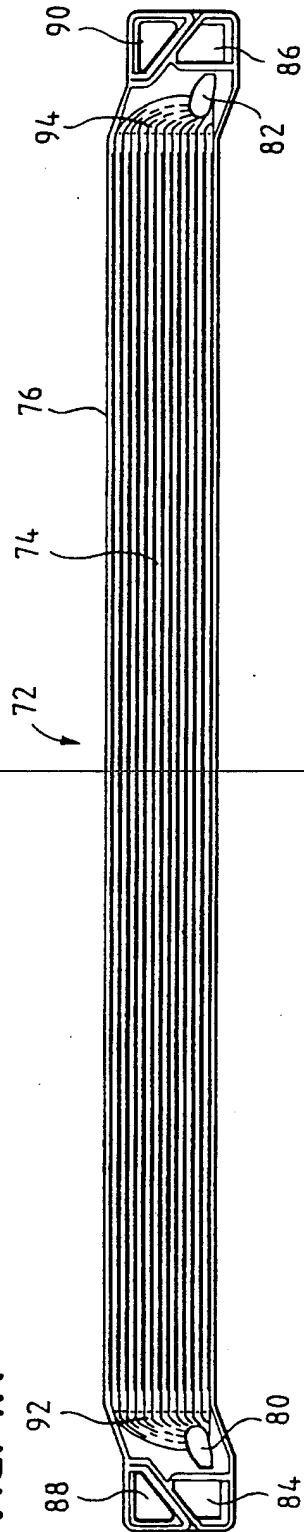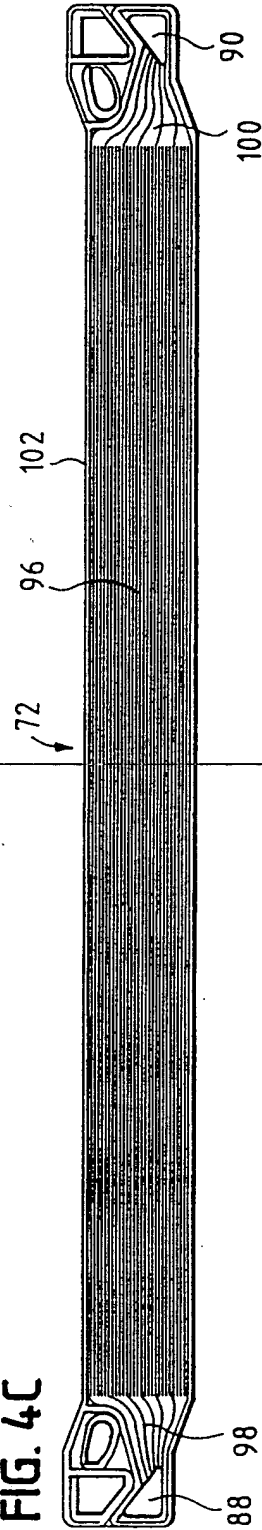
According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)
IPC 7   H01M

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

PAJ, EPO-Internal, WPI Data

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category * | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| A | US 5 527 363 A (WILKINSON DAVID P ET AL) 18 June 1996 (1996-06-18) abstract column 2, line 34 – line 53 claims | 1,27,44, 51 |
| A | PATENT ABSTRACTS OF JAPAN vol. 1997, no. 05, 30 May 1997 (1997-05-30) -& JP 09 007615 A (TANAKA KIKINZOKU KOGYO KK), 10 January 1997 (1997-01-10) abstract | 1,22,27 |
| | —/— | |

[X] Further documents are listed in the continuation of box C.          [X] Patent family members are listed in annex.

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| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 26 July 2000 | 01/08/2000 |

| Name and mailing address of the ISA | Authorized officer |
|---|---|
| European Patent Office. P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl. Fax: (+31–70) 340–3016 | Riba Vilanova, M |

Form PCT/ISA/210 (second sheet) (July 1992)

Intern     nal Application No

PCT/CA 99/01214

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

| Category ° | Citation of document, with indication,where appropriate, of the relevant passages | Relevant to claim No. |
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| Patent document cited in search report | | Publication date | Patent family member(s) | | Publication date |
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| JP 04303566 | A | 27-10-1992 | NONE | | |
| US 6007933 | A | 28-12-1999 | NONE | | |